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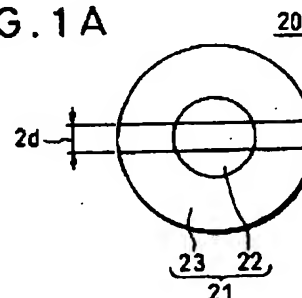
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(54) **OPTICAL FIBER WITH LENS**

(57) There is provided a lensed optical fiber (20) in which a lens is formed on the end face of an optical fiber to enhance the efficiency of optical coupling with a light beam. The tip end portion of an optical fiber (21) is formed with a lens (26) formed into a wedge shape having two slant portions (24) symmetrical with respect to an axis (Ac) of a core (22) and a plane portion (25) perpendicular to the axis of the core.

FIG. 1A



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Description

TECHNICAL FIELD

[0001] The present invention relates to a lensed optical fiber in which a lens is formed on the end face of an optical fiber to enhance the efficiency of optical coupling with a light beam.

BACKGROUND ART

[0002] In order to enhance the efficiency of optical coupling of a light beam from a light source such as a laser diode device with an optical fiber, there has been used a lensed optical fiber in which a lens is formed on the end face of an optical fiber. For example, as shown in FIG. 4, a lens 2 formed on the end face of an optical fiber 1 has an external form consisting of a hyperboloidal portion 2a and a spherical portion 2b inscribed in the hyperboloidal portion 2a. The optical fiber 1 having the lens 2 of this form has a high efficiency of optical coupling with a light source. For laser diode having a generating wavelength of $0.98\text{ }\mu\text{m}$ at the center, the maximum optical coupling efficiency can be obtained when a radius R of the spherical portion 2b inscribed in the hyperboloidal portion 2a is generally 1.5 to $5\text{ }\mu\text{m}$ (see USP No. 5,256,851).

[0003] As shown in FIG. 5, there also has been proposed an optical fiber having a lens 12 of a wedge-shaped external form having two-stage tapered portions 12a and 12b with different angles of θ_1 and θ_2 , respectively (see USP No. 5,455,879). An optical fiber 11 having a lens 12 of a form shown in FIG. 5 also exhibits a high optical coupling efficiency.

[0004] However, the aforementioned lensed optical fibers have the following problems:

1) For the lens 2 of the first form shown in FIG. 4, the hyperboloidal portion 2a is formed by being polished using a flat plate polishing machine while the angle between the optical fiber and the polishing machine is adjusted. Therefore, for the lens 2 of the first form, it is difficult to fabricate the hyperboloidal portion 2a with high reproducibility, so that the yield decreases. Also, the optical coupling efficiency varies sensitively depending on the diameter of the spherical portion 2b, which also results in a decrease in yield.

For the lens 2 of this form, it is difficult to accurately determine the boundary between the hyperboloidal portion 2a and the spherical portion 2b when the radius of the spherical portion 2b inscribed in the hyperboloidal portion 2a is measured. Therefore, the lens 2 of this form presents a problem in that the inspection for external form takes much time.

2) The lens 12 of the second form shown in FIG. 5 is polished while the angle between the optical fiber

11 and the polishing machine is kept constant. Therefore, the lens 12 of the second form can be fabricated more easily than the lens 2 of the first form. However, for the lens 12 of the second form, because two-stage tapered portions 12a and 12b with different angles of θ_1 and θ_2 are formed, the fabrication takes much time, and the reproducibility of form and increase in yield are limited.

[0005] Accordingly, an object of the present invention is to provide a lensed optical fiber which has no aforementioned drawbacks of the conventional lensed optical fibers and, more specifically, to provide a lensed optical fiber which has a high efficiency of optical coupling with a light source, and can be fabricated with high fabrication accuracy and high yield.

DISCLOSURE OF THE INVENTION

[0006] The present invention has been made based on a new knowledge obtained as a result of earnest theoretical study of the conventional lensed optical fiber. The present invention provides a lensed optical fiber in which a lens is formed at the tip end of an optical fiber having a core and a cladding, characterized in that the lens is formed into a wedge shape having two slant portions symmetrical with respect to an axis of the core and a plane portion perpendicular to the axis of the core.

[0007] The lensed optical fiber having the tip end portion of the aforementioned shape has a high optical coupling efficiency. Also, since the shape of this tip end portion is a simple one formed by three planes, the lensed optical fiber can easily be fabricated with high accuracy and high yield. Also, the inspection for external form can be made easily.

[0008] Preferably, an angle between the slant portion and the plane portion is set at 110 to 170° , and the distance between two intersecting lines on which the slant portion and the plane portion intersect with each other is set at 1 to $4\text{ }\mu\text{m}$. Thereby, the lensed optical fiber in accordance with the present invention preferably has an efficiency of 40% or higher of optical coupling with a light source.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1A is a front view of a tip end portion of one embodiment of a lensed optical fiber in accordance with the present invention;

FIG. 1B is a side view of a tip end portion of the lensed optical fiber shown in FIG. 1A;

FIG. 2 is a view for illustrating the measurement of optical coupling efficiency of the above embodiment;

FIG. 3 is a characteristic diagram showing the relationship between an angle θ which a slant portion

makes with a plane portion and the optical coupling efficiency for the above embodiment;

FIG. 4 is a perspective view of a conventional lensed optical fiber; and

FIG. 5 is a schematic view of another conventional lensed optical fiber.

BEST MODE OF CARRYING OFF THE INVENTION

[0010] An embodiment of the present invention will be described in detail with reference to the accompanying drawings.

[0011] FIG. 1A and FIG. 1B are a front view and a side view, respectively, of a tip end portion of one embodiment of a lensed optical fiber 20 in accordance with the present invention. In the figures, an optical fiber 21 has a core 22 with a circular cross-sectional shape and a cladding 23. The tip end portion of the optical fiber 21 is formed with a lens 26 consisting of a wedge-shaped portion formed by two slant portions 24 which is symmetrical with respect to a core axis Ac and a plane portion 25 which is perpendicular to the core axis Ac. An angle which the slant portion 24 makes with the plane portion 25 is taken as θ , and a distance between two intersecting lines on which the slant portion 24 and the plane portion 25 intersect with each other is taken as 2d.

[0012] The aforementioned lensed optical fiber 20 was manufactured by a fabrication procedure as described below.

[0013] First, the tip end of the optical fiber 21 was cleaved to form the plane portion 25 which was perpendicular to the core axis Ac.

[0014] Next, the optical fiber 21 was polished while an angle between a flat plate polishing machine and the core axis Ac is kept at a desired angle ($\theta - 90^\circ$) using a jig. By this polishing process, the tip end of the optical fiber 21 could be made the wedge-shaped lens 26.

[0015] As described above, the lensed optical fiber 20 of this embodiment can be manufactured by cleaving the tip end into the plane portion 25 and by polishing the slant portion 24 at the tip end of the optical fiber 21 by onetime angle control. For the lensed optical fiber 20, therefore, the fabrication process was very simple, the yield was increased easily, and the fabrication cost was decreased.

[0016] For the lensed optical fiber 20, the optical coupling efficiency was evaluated under the conditions shown in FIG. 2.

[0017] A laser diode, for example, having a generating wavelength of 0.98 μm at the center was used as a light source 30, and the intensity distribution (mode field) pattern of emitted light from the light source 30 was made an ellipse having a major axis of 4.8 μm and a minor axis length of 1.2 μm . Also, the mode field pattern of the optical fiber 21 constituting the lensed optical fiber 20 was made a circle having a diameter of 6.0 μm . Here, the distance between the light source 30 and the

lensed optical fiber 20 was made the optimum distance at which the highest optical coupling efficiency can be obtained, for example, 10 μm , and the minor axis direction of the mode field pattern of the light source 30 was made a direction perpendicular to the direction of the intersecting line on which the slant portion 24 and the plane portion 25 intersect with each other.

[0018] Under the above conditions, the efficiency of optical coupling with the light source 30 was evaluated by changing the angle θ between the slant portion 24 and the plane portion 25 with the distance between two intersecting lines on which the slant portion 24 and the plane portion 25 intersect with each other being used as a parameter.

[0019] The results are shown in FIG. 3, in which the abscissa represents $(180 - \theta)$ and the ordinate represents the coupling efficiency.

[0020] Here, the optical coupling efficiency was obtained from $P2/P1$, where P1 is the whole power of light emitted from the light source 30, and P2 is the power of light incident on the optical fiber.

[0021] As seen from FIG. 3, in the range of 1.0 to 4.0 μm of the distance 2d and 110 to 170° of the angle θ (in the figure, $(180 - \theta) = 10$ to 70°), an efficiency of 40% or higher of optical coupling with the light source 30 was obtained. In particular, in the case where 2d = 2.0 μm and $\theta = 140$ to 150° ($(180 - \theta) = 30$ to 40°), an optical coupling efficiency as high as 90% was obtained.

[0022] As a comparative example, the optical coupling efficiency of a lensed optical fiber, in which the tip end portion is not of a planar shape perpendicular to the core axis Ac and a lens 2 shown in FIG. 4 is formed, was measured under the aforementioned conditions. As a result, an optical coupling efficiency of 97% at a maximum was obtained.

[0023] Thus, the lensed optical fiber of this embodiment exhibits a high optical coupling efficiency which is by no means inferior to the comparative example. Considering the high workability, an excellent lensed optical fiber which can be mass-produced at a low cost can be provided.

INDUSTRIAL APPLICABILITY

[0024] The present invention offers an excellent effect that there can be obtained a lensed optical fiber which has a high optical coupling efficiency and can be fabricated with high accuracy and high yield.

Claims

1. A lensed optical fiber in which a lens is formed at the tip end of an optical fiber having a core and a cladding, characterized in that said lens is formed into a wedge shape having two slant portions symmetrical with respect to an axis of said core and a plane portion perpendicular to the axis of said core.

2. A lensed optical fiber according to claim 1, wherein an angle between said slant portion and said plane portion is 110 to 170°, and the distance between two intersecting lines on which said slant portion and said plane portion intersect with each other is 1 to 4 μm .

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FIG. 1A

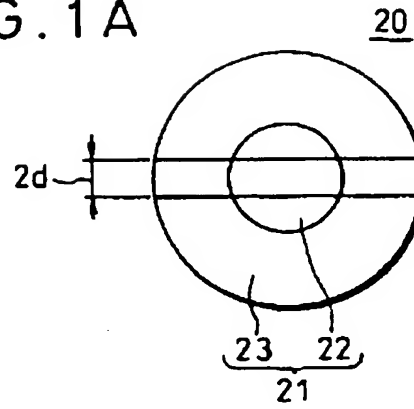


FIG. 1B

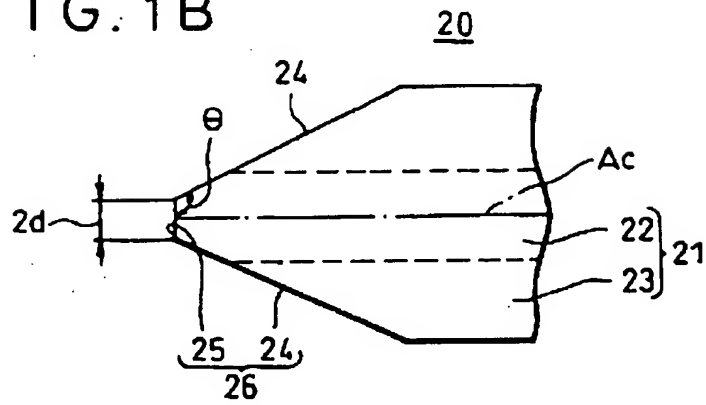


FIG. 2

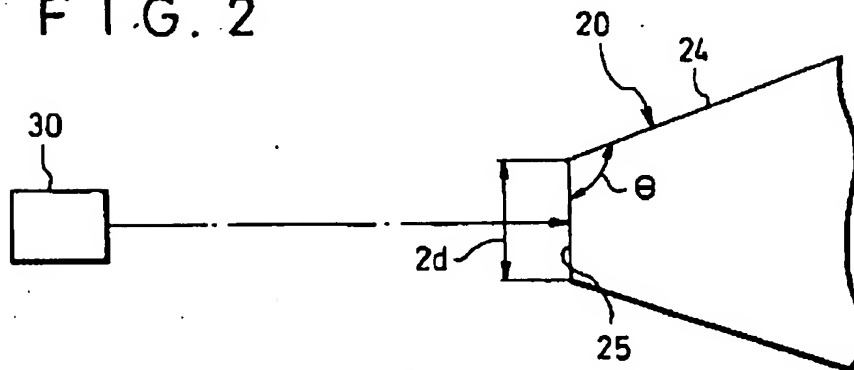


FIG. 3

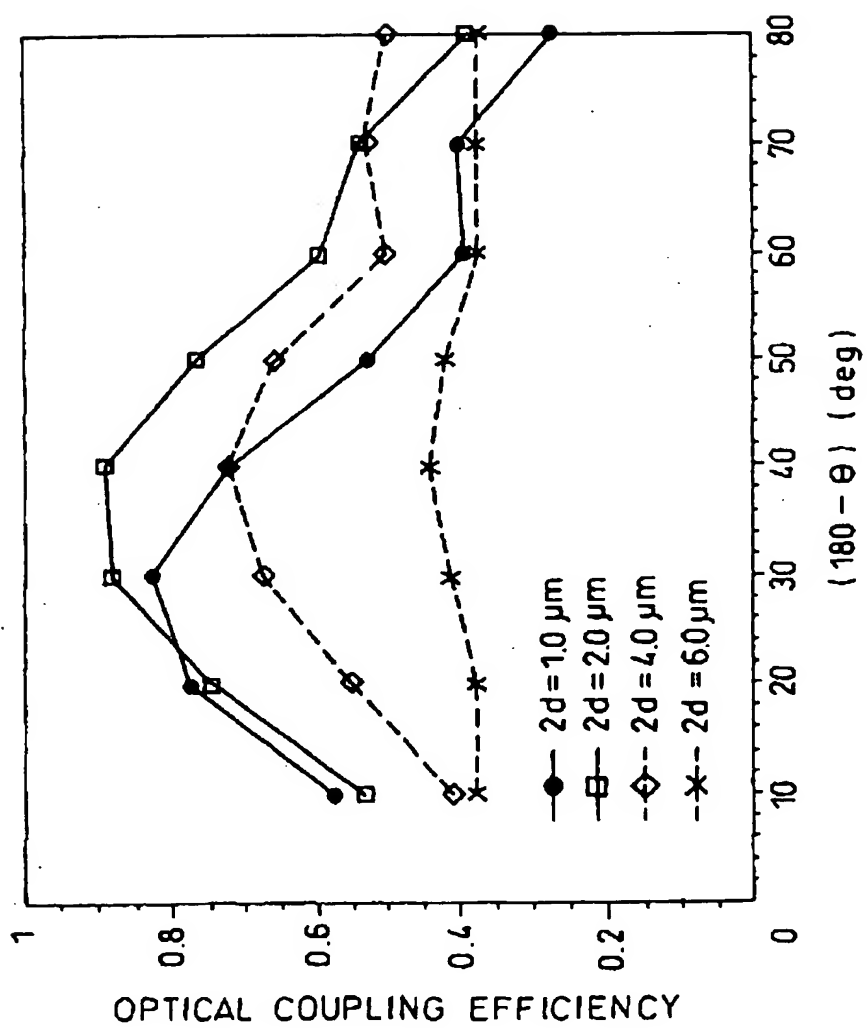


FIG. 4

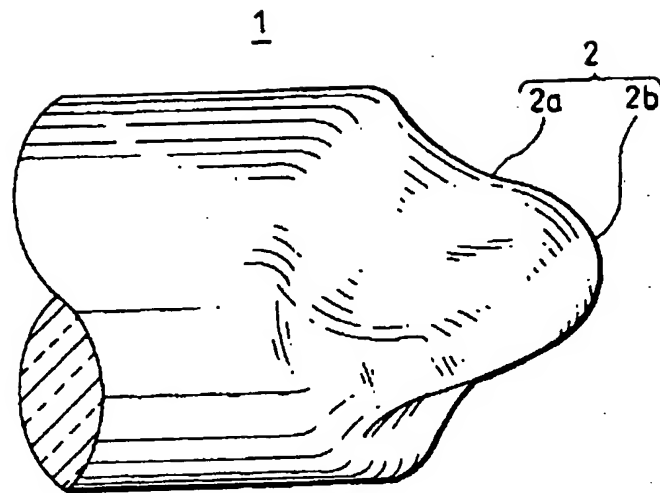
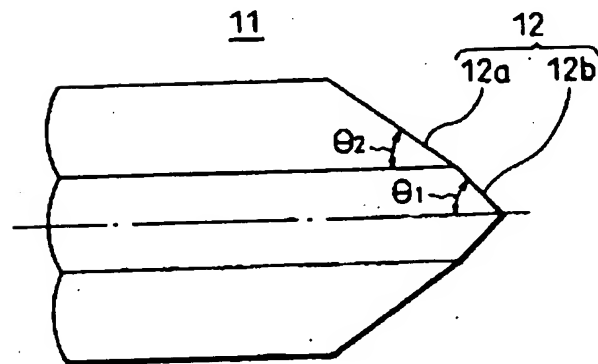


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP98/01730

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl¹ G02B6/32, 6/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl¹ G02B6/32, 6/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926-1998

Kokai Jitsuyo Shinan Koho 1971-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 55-153384, A (Nippon Telegraph & Telephone Public Corp.), November 29, 1980 (29. 11. 80) (Family: none)	1, 2
A	JP, 61-256310, A (Matsushita Electric Industrial Co., Ltd.), November 13, 1986 (13. 11. 86) (Family: none)	1, 2
A	JP, 4-91302, U (Stanley Electric Co., Ltd.), August 10, 1992 (10. 08. 92) (Family: none)	1, 2
A	JP, 6-67061, A (Nippon Sheet Glass Co., Ltd.), March 11, 1994 (11. 03. 94) & EP, 583986, A3 & US, 5416881, A	1, 2
A	US, 5455879, A (Corning Incorporated), November 3, 1995 (03. 11. 95) (Family: none)	1, 2

☐ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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 Date of the actual completion of the international search
 July 2, 1998 (02. 07. 98)

 Date of mailing of the international search report
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